VOLTAGE-DRIVEN TYPE SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a voltage-driven type semiconductor device, and more particularly to a voltage-driven type semiconductor device suitable to be used for a power converter and a power source of various power capacities, a power amplifier, an oscillator, an analog switch or the like as a single device or by integrating a plurality of such devices into an IC.

As voltage-driven type semiconductor devices of this sort according to prior art techniques, a MOSFET, an SI transistor, an IGBT, a MOS thyristor and so on are known. Being driven by voltage, these semiconductor devices have such a feature that the power dissipation for driving is very small as compared with a current-driven type semiconductor device. Further, MOSFETs and SI transistors have an advantage that an on-current can be applied even in case of low on-voltage in the vicinity of 0 V. On the other hand, in such devices it is required to relieve an electric field intensity by expanding a depletion layer into a drain region and also to lower impurity concentration in the drain region in order to use the devices at a high voltage.

Thus, in a high voltage MOSFET and a high voltage SI transistor, resistance of a drain region becomes high. As a result, the on-resistance of the whole element becomes high, and the power dissipation of the element becomes very large.

A different type of voltage-driven device, known as an IGBT, is described in, for instance, JP-A-4-11780.

The IGBT according to this prior art arrangement is a voltage-driven type semiconductor device in which an emitter for carrier injection is connected to a drain of a MOSFET. Since carriers (such as holes) are injected into the drain in the on-state of the element and conductivity modulation is produced, the IGBT has such an advantage that the on-resistance thereof can be reduced to approximately ¼ of that of a MOSFET even when it is designed for a high voltage. A consequence, it is possible to reduce the power dissipation of the device by a large margin.

The IGBT which is a voltage-driven type semi-conductor device, however, is latched up when carriers (such as electrons) having a different polarity are injected from the source thereof. Therefore, it is of vital importance to check injection of the carriers having a different polarity, thereby to prevent voltage control from becoming inexecutable by latch-up.

Another prior art technique is described in, for example, IEEE Trans. Electron Devices, Vol. ED-33, pp. 1609–1618 (1986) written by V.A.K. Temple, JP-A-3-87068, and is known as a prior art arrangement related to a MOS thyristor which is a voltage-driven type semiconductor device.

A MOS thyristor according to this prior art arrangement has basically a pnpn structure similar to that of an IGBT, in which carriers (such as electrons) are injected positively also from an emitter corresponding to a source of the IGBT and conductivity modulation in a base region corresponding to a drain of the IGBT is made deeper so as to generate latch-up, thereby to further reduce the on-resistance even more than an IGBT. Thus, it is possible to reduce the power dissipation in this MOS thyristor lower than the IGBT described above by a large margin.

However, it has been required in such prior art MOS thyristors to include inside the MOSFET an arrangement for

short-circuiting the emitter junction in order to make it possible to control the off-voltage after latch-up.

Since the on-resistance can be reduced remarkably in the IGBT and the MOS thyristor according to a prior art as compared with a MOSFET as described above, they are suitable to be used for high voltage and large current. In these elements, however, it is impossible to apply a current from the vicinity of 0 V, and voltage drop caused by the junction at about 0.6 to 0.8 V exists. Therefore, power dissipation by the voltage drop portion is produced even if conductivity modulation is made sufficiently deep, thus limiting reduction in power dissipation of the whole element. Namely, a linear characteristic has been unobtainable in volt-ampere characteristics of these elements.

The voltage-driven type semiconductor device such as an IGBT and a MOS thyristor according to a prior art described above has a problem that reduction of power dissipation of the whole element is limited since voltage drop caused by the junction at about 0.6 to 0.8 V exists and power dissipation caused by the voltage drop portion is produced even when conductivity modulation is made sufficiently deep.

SUMMARY OF THE INVENTION

It is an object of the present invention to solve the problem described above and have a voltage-driven type semiconductor device be provided with the effect of reduction of the on-resistance by conductivity modulation like an IGBT and a MOS thyristor, and to provide a voltage-driven type semiconductor device capable of substantially eliminating the voltage drop caused in prior art devices by the junction, reducing power dissipation to the minimum, and in particular, capable of obtaining remarkable effects of reducing power dissipation in use for high breakdown voltage and high current.

According to the present invention, the above-mentioned object can be achieved by merging a drain of a voltage-driven type transistor such as a MOSFET and an SI transistor with a bipolar transistor having an emitter composed of a semiconductor of the same conductivity type as that of this drain, viz., by providing an emitter of a bipolar transistor of the same polarity and then a base and a collector successively with the drain of the voltage-driven type transistor.

Further, the above-mentioned object is achieved by merging the drain of the voltage-driven type transistor with the emitter of the bipolar transistor in one.

In a voltage-driven type semiconductor device according to the present invention, carriers (such as electrons) flow from the source of the voltage-driven type transistor to the drain through a channel at time of on-operation. The carriers (such as electrons) flow into the emitter of the bipolar transistor as they are since the drain and the emitter of the bipolar transistor are formed of semiconductor regions of the same conductivity type.

These carriers (such as electrons) flowing into the emitter are injected into the base of the bipolar transistor, thus generating transistor operation. When an injection efficiency of the carriers (such as electrons) into the base and a transfer efficiency of the carriers in the base are kept high, the transistor is brought into a saturation state easily. As is generally known, since junctions of the emitter and the collector of the transistor are both brought into a forward bias state in the saturated state, the collector saturation voltage corresponding to the difference between both forward bias states is very small, thus making it possible to make a collector saturation resistance very small.